Uncertainties in Calculation of Radiative Forcing by Carbon Dioxide

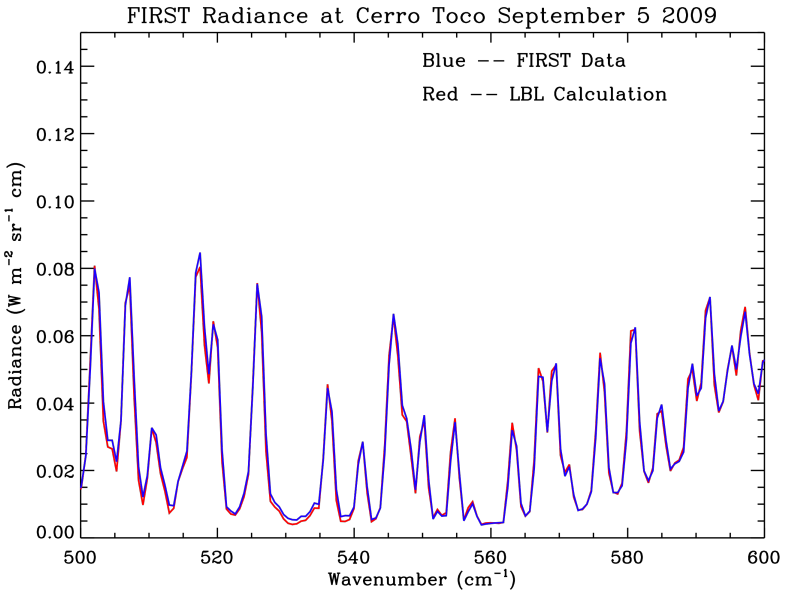
Marty Mlynczak, Dan Feldman, Bill Collins

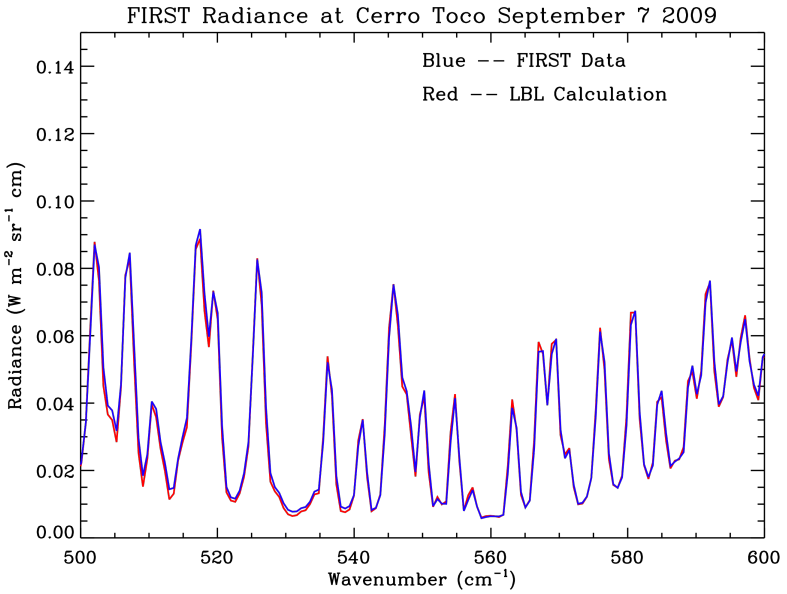
CLARREO SDT Meeting
October 2014

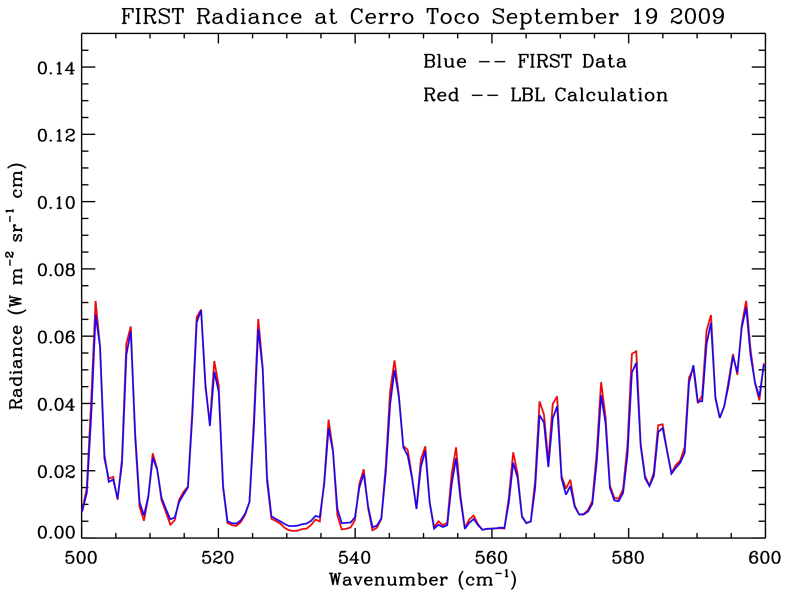
Background/Outline

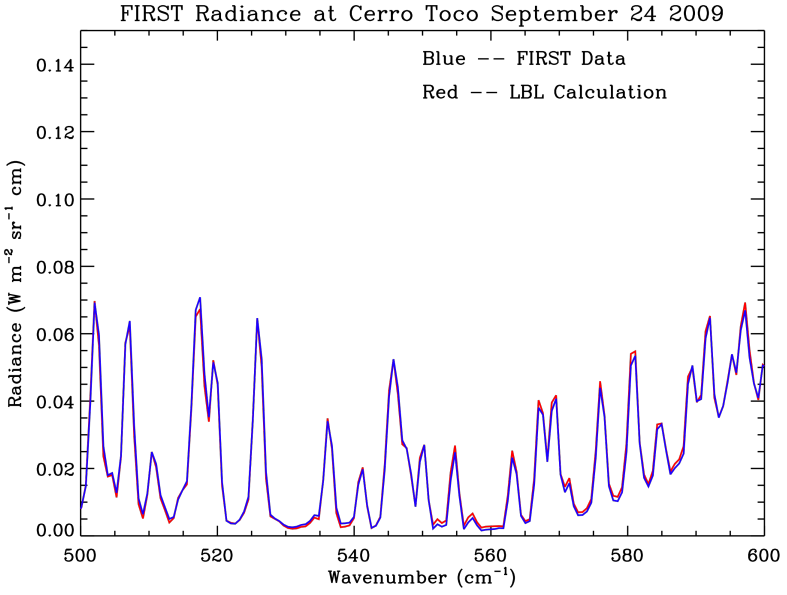
- General background - FIRST data at WCRP Denver
- Introduce the issue raised by Prof. W. Happer, Princeton, of how well radiative forcing by CO_2 is calculated
- Review involvement of CLARREO team members, NOAA, U-Wisconsin, AER
- Present the path forward to resolving this issue
- Discuss new measurements that may be needed

FIRST Data 500 – 600 cm^{-1}; September 5, 7, 19, 24
Cerro Toco, Chile









Presented at WCRP 2011 Conference, Denver

Background

- In Oct 2013, David Fahey (NOAA) inquires about the FIRST data shown at WCRP in October 2011
- Mentions that the data show no large differences between measurement and theory
- We discussed lineshapes, modeling, etc.
- Discusses claims being made in 2013 by Will Happer, Professor of Physics, Princeton
- The claim is:
  - Radiative forcing by CO_2, and hence global warming, is overestimated by 40% or more due to use of Voigt lineshape in climate models
  - Hence the "pause" in global warming
- The claim is false – sub-lorentzian wings in CO_2 have been known (FASCOD2, 1982; Fels and Schwarzkopf, 1981)

Background (2)

- UW physicists J. Lawler, W. Anderson contacted Fahey to see if the lineshape claim was true
- Apparently this claim has been presented at DoE labs and at university seminars
- Fahey contacted Mlynczak because of his recollection of the FIRST data
- Discussion then broadened to include Bill Collins, Dan Feldman, Dave Tobin, and Eli Mlawer
  - Significant concern over consequences of claim
- Mlynczak contacts Happer via email several times. Points out lineshape is known to be sub-lorentzian; fast codes used in climate models based on lab-measured lineshapes, etc.
- Extensive literature on CO_2 sub-lorentzian lineshape – which is incorporated in LBLRTM and other standard codes
- Happer's talk is now published…

International Journal of Modern Physics A
Vol. 29, No. 7 (2014) 1460003 (34 pages)

DOI: 10.1142/S0217751X14600033

Why has global warming paused?*

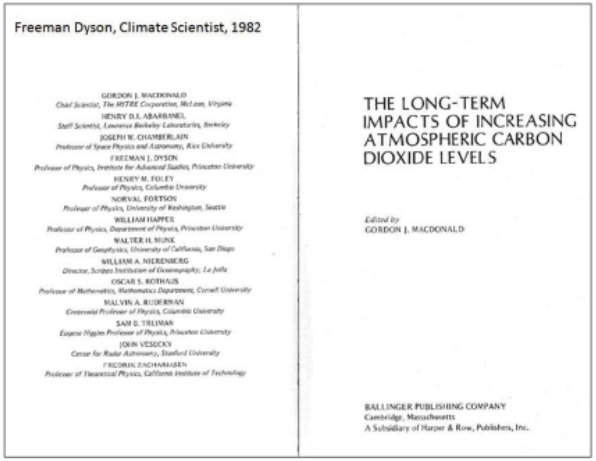
William Happer
Department of Physics, Princeton University, Princeton, NJ 08544, USA
happer@princeton.edu

Received 29 November 2013
Revised 10 February 2014
Accepted 13 February 2014
Published 11 March 2014

1. Introduction

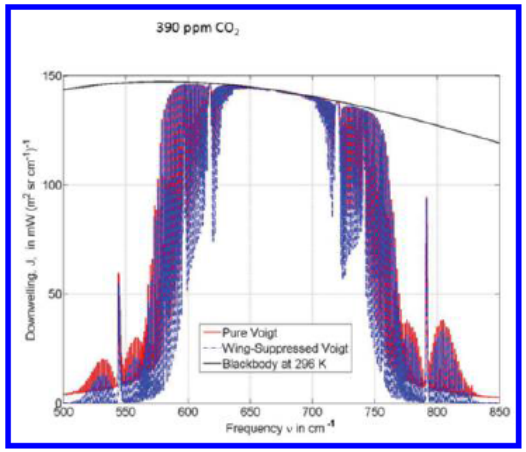
Freeman Dyson has been interested in climate for most of his life. He coauthored one of the earliest books on the interplay of CO_2 and climate in 1982:

> "The Long-term Impacts of Increasing Atmospheric Carbon Dioxide Levels", edited by Gordon J. MacDonald (Ballinger Publishing Company, 2008).



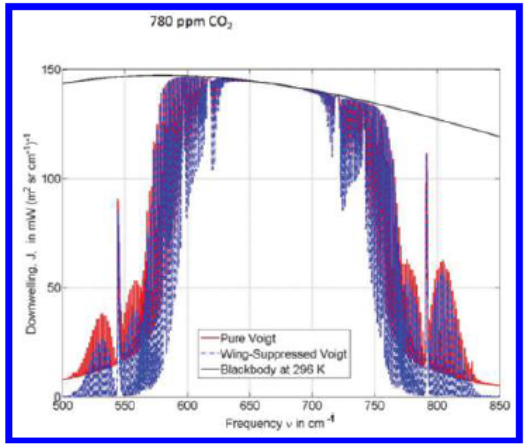
Slide 1.

*Based on a talk given at the conference *Dreams of Earth and Sky: A Celebration for Freeman Dyson*, Institute for Advanced Study, Princeton, 27 September 2013.



Slide 35.

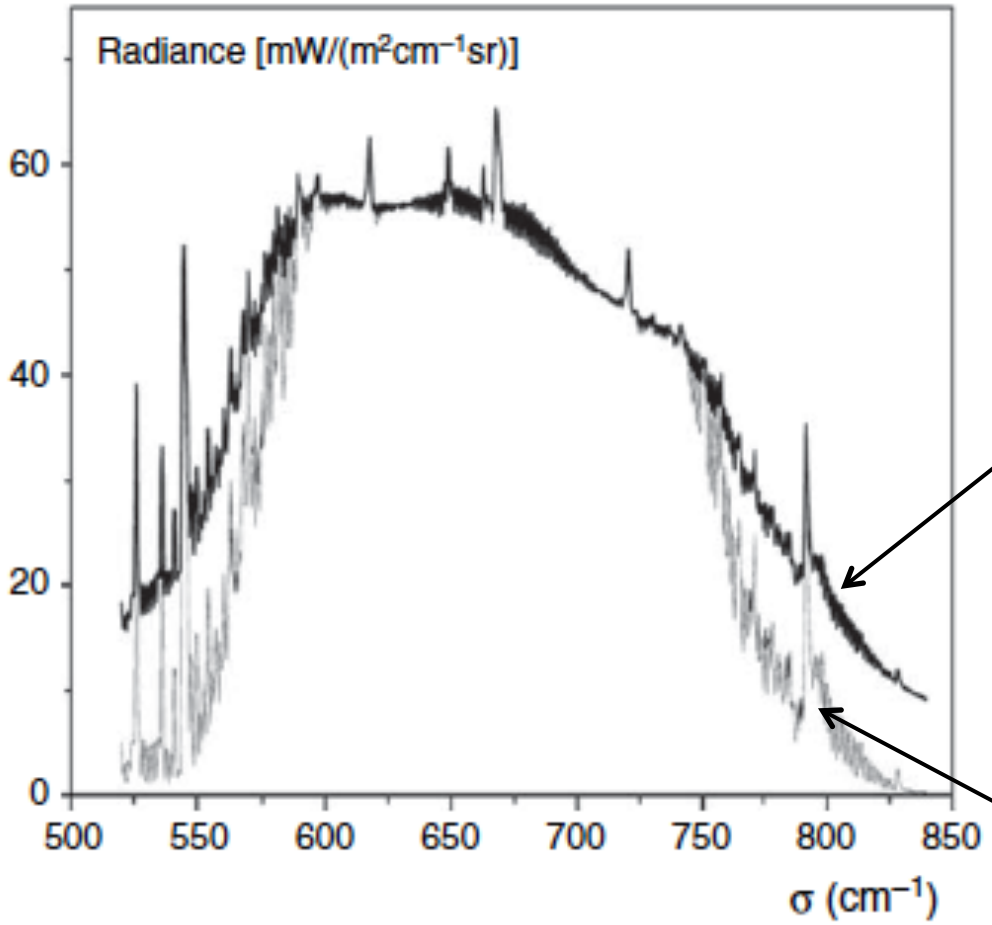
This is a modelled downwelling spectrum at the earth's surface. It comes from CO_2 in a cloud-free atmosphere with no other greenhouse molecules, notably no H_2O. The assumed line profile makes very little difference near the center of the band, but it makes a big difference in the far wings. The assumed CO_2 concentration, 390 ppm, is close to today's value.



Slide 36.

This is modelled in the same way as for the previous slide, only with twice the CO_2 concentration. Doubling the CO_2 concentration makes no difference near line center, but it does add more downwelling radiation in the wings.

Further Proof that the CO_2 lineshape is sub-Lorentzian

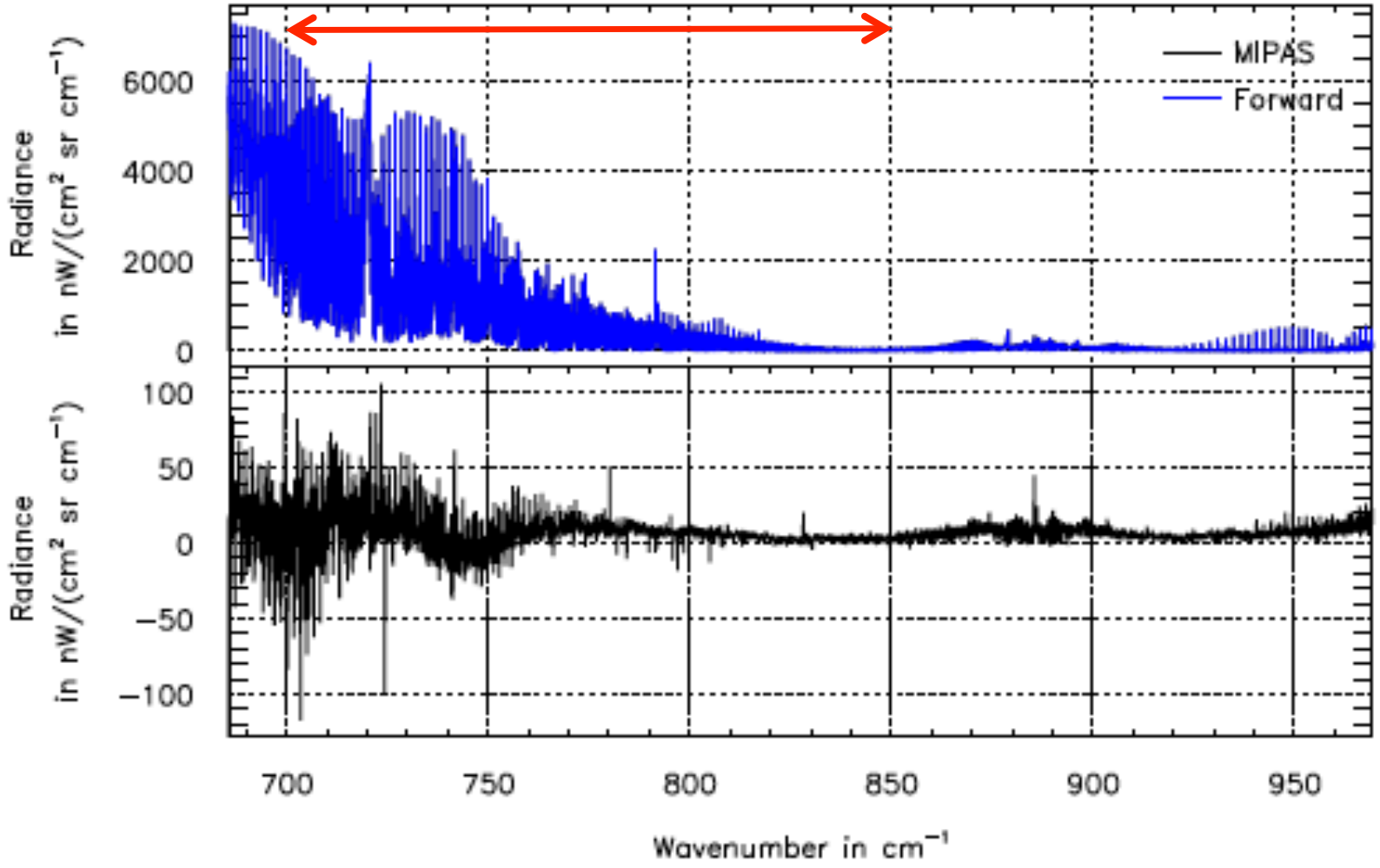


LBL calculation with Voigt lineshape

FIRS-2 spectrum
40 km altitude, looking through limb to 10 km

MIPAS/EnviSAT IR spectrum at 30 km compared with KOPRA LBL model

Measured and modeled spectra agree to within a few percent in wings



Plieninger et al., JQSRT, 2012
Figure courtesy G. Stiller, U. Karlsruhe

Current Status

- **Mlynczak, Feldman, Collins are working together and conduct a study of the uncertainty in calculation of radiative forcing by CO_2**
- **First step was a 2-week visit to Berkeley by Mlynczak, 9/2014**
- **Goal is to have a paper assessing the uncertainties in the computation of radiative forcing**

Approach (1)

- Consider all aspects of the calculation of radiative forcing:
  - Spectroscopy (S, α_L, α_s, n)
  - Line shape
  - Fast RT codes (e.g., RRTM) vs. line-by-line calculations
  - Other line parameters (line position, pressure shift) are not at issue

- HITRAN specifies uncertainties for all of the relevant line parameters

- We will compute difference in radiative forcing for doubled CO_2 – with baseline spectroscopic parameters, and for line parameters perturbed by specified uncertainty

- To avoid having to do this for tens of thousands of model profiles, Dan F. looking at Monte Carlo analyses to select small range of atmospheres that are representative of global mean

Approach (2)

- Evaluate effects of uncertainty in lineshape
  - $k\nu' = k\nu*(1 + q(\nu - \nu_o))$
  - $q(\nu - \nu_o)$ is an uncertainty function applied to the baseline cross section
- Compute radiative forcing with and without a perturbed lineshape, assess differences as the uncertainty
- Assess effects of fast radiative transfer codes vs. LBL in the same manner
- At the end, we will have an assessment of the uncertainty in the computation of radiative forcing due to:
  - Spectral line parameters
  - Line shape function
  - Radiative transfer models
- Lastly we will compute the spectral radiative forcing and identify which lines and bands are important in the radiative forcing

Anticipated Outcomes

- A quantitative assessment of uncertainty in radiative forcing by carbon dioxide
  - Expectation is that the major uncertainty is introduced by RT codes and not the spectroscopy
  - CO_2 halfwidths known to ~ 1% [Gamache and Lamouroux, 2013]
- First definition of spectral structure of radiative forcing
  - By specific CO_2 bands and per wavenumber
- Recommendations for improvement of line/band strength for the specific CO_2 bands most involved in the forcing
- Recommendations for improvement in the spectral lineshape function
  - Measurement at < 1 atm; Current shape measured at very high pressures

Working Group

- Langley (Mlynczak; Kratz; Mast)
- Wisconsin (Lawler; Anderson; Tobin)
- LBNL (Feldman; Collins)
- NOAA (Fahey)
- Karlsruhe Institute of Technology (Stiller, von Clarmann)
- Others to be included

- Comments and suggestions welcomed!